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Applications of the Theories of Mikhail Bakhtin in Science Education

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APPLICATIONS OF THE THEORIES OF MIKHAIL BAKHTIN IN SCIENCE EDUCATION

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Abstract

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The purpose of this literature review is to investigate the work of Russian philosopher and literary critic Mikhail Bakhtin (1895 – 1975), and more specifically, how his theories on language in a social context apply to science education. In response to ongoing concerns regarding declining student achievement in the sciences, this paper follows a growing trend to integrate perspectives from the fields of language, anthropology and sociology, in order to reform science instruction and improve student scientific literacy. Bakhtin's major theories around dialogue, and his views on the celebration of carnival, are presented through an analysis of secondary resources that apply some of his well-known literary works to the classroom. The underlying theme of these theories, that of learning made possible through dialogic interaction, leads the discussion for application of Bakhtin's theories to the classroom. An extensive review of available literature that studies Bakhtin's theories, and literature that indirectly references dialogue and carnival as pedagogical tools, are all synthesized and then analyzed in an attempt to demonstrate their effectiveness in the science classroom. Concluding the paper is a summary of common themes, suggestions for how science curriculum should be structured, and implications for science education.

Keywords: Mikhail Bakhtin, science curriculum, dialogic pedagogy, dialogue, carnival

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Introduction & Purpose

In 2006, The Organization for Economic Co-Operation and Development (OECD) developed an ongoing international study named the *Programme for International Student Assessment* (PISA) to assess student performance across countries in mathematics, reading, and science. The report findings stressed the imperativeness of improving science and technology education in modern societies in order for these countries to stay competitive in the ever-expanding global market (OECD, 2007, p. 3). Furthermore, the authors note that while science is traditionally taught as science content knowledge, the modern world requires a fundamental shift to where science education involves teaching how to think critically, apply previous knowledge to solve new problems, and explain decisions using evidence (OECD, 2007, p. 113). However, based on student performance assessments, an average of only 9.0% of fifteen year olds who participated in the study performed at the highest proficiency levels in these skill areas, and an average of 19.5% did not even show beginning development in these skills (OECD, 2007, p. 113). Unfortunately, the United States is not only part of this downward trend, but is one of the countries that are consistently failing to educate its students in the sciences (Yerrick & Roth, 2005, p. 1). In other international studies, such as the *Trends in International Mathematics and Science Study* (TIMSS), the United States' science scores still have not increased since its inception and the percentage of students at or above advanced international standards are lower than other developed countries (NCES, 2008). The poor performance of the United States on assessments such as the PISA, TIMSS, and the *National Commission on Mathematics and*

Science Teaching for the 21st Century (2000) have brought harsh criticism on the current state of science education in this country (Yerrick & Roth, 2005, p. 1).

While rapid globalization is a current trend that is fueling these re-evaluations of the methods of science education, it is not the first time that methodologies behind science instruction have been questioned. Even as far back as the early 1900s, influential educational philosopher John Dewey discerned that science instruction had too much emphasis on facts and not enough focus on developing thinking skills (Barrow, 2006, p. 266). Foreign relations have also frequently influenced science educational policy, as seen from the United States' reaction to the launch of Sputnik I in 1957, resulting in the National Science Foundation's new curricula with the emphasis of teaching science from the perspective of the scientist (Barrow, 2006, p. 267). Consequently, it should come as of no surprise that in light of the recent low performance on international studies, there are currently equal amounts legislators, scientists, and educators interested in reforming science education (Yerrick & Roth, 2005, p. 1). Yet, one would have to question the methodology of these attempted reforms if students are still falling behind and continue to perform worse in international studies year after year. In response to this dilemma, experts within the fields of anthropology, sociology, and linguistics have begun to explore the nature of science and the behavior of scientists in an effort to diversify approaches to teaching science, with increasingly successful results (Yerrick & Roth, 2005, pp. 1-2). As more science educators begin to integrate sociolinguistic theories in an attempt to improve science instruction and student scientific literacy, many theorists who had previously been restricted to applications in language arts classes gain new relevance in the sciences. One such theorist, whose ideas regarding language and learning are the central piece of this literature review, is Mikhail

Mikhailovich Bakhtin (1895 – 1975), a Russian philosopher and literary critic whose works potentially hold major solutions to the aforementioned problems with science education.

My interest in researching the theories of Mikhail Bakhtin, and how they apply to science education, stem from my experiences as both a teacher and student of science. Inspired by my non-traditional high school physics teacher, I entered my undergraduate program pursuing a degree in teaching high school physics. While my teaching methods courses taught the importance of student-centered, hands-on, inquiry-based learning as a science teacher; all but one of my college-level science courses were taught as the antithesis of this, as strict lecture-based courses with minimal lab activities. However, in the class where I felt that I had learned the most, was where the teacher treated us as scientists. In this class, we were required to collaboratively develop our own experiments based off of the class discussion questions, present our findings as a group of scientific peers, and interact with members of the scientific community through symposiums and writings. When I eventually got the chance to teach my own class, I attempted to carry over numerous of these activities that provided students with hands-on lab activities, which absolutely were key components in the student learning. Though, it was an unexpected 'bell-ringer' activity that provided me some of my greatest success as a science teacher. Looking for a way to engage students at the beginning of class, I posed a different daily question about a common scientific phenomenon, such as "Why do you hear the ocean when you put your ear to a sea shell?" Students were directed to write their thoughts in their journals, debate amongst themselves using their thoughts and rationale to support their claims, and finally, participate in a demo or lab activity to answer these questions. I originally accredited the student success from these methods solely to the fact that they were participating in lab activities;

nonetheless, in doing so, I wrongly ignored essential components of the learning process that Bakhtin's theories shed light on.

After being exposed to the theories of Mikhail Bakhtin as a graduate student, I came to realize that structuring learning activities where students perform science experiments is crucial, but not necessarily the complete solution to improving poor student achievement in science. In fact, the science curriculum introduced in the 1950's emphasized performing science experiments in the classroom, which has not had a lasting effect on improving education (Barrow, 2006, p. 267). What has been ignored, and what was present in my examples, was the presence of instructional methods that integrate sociolinguistic components – the fundamental core underlying all of Bakhtin's theories investigated in this literature review. To generalize Bakhtin's theories and applications towards education, it would be that learning occurs through dialogical processes and within "social learning spaces" (Zack & Graves, 2001, p. 235). In both of my examples, the lab investigations gave way to a construction of knowledge through dialogue amongst peers and other members of the scientific community, which enhanced the student learning. Supporting this idea, the increased interest in alternative approaches to science education reform has produced a number of studies that apply Bakhtin's theories to science education with similar results. Consequentially, the purpose of this paper is to capture a large number of these studies that either explicitly or implicitly reference Bakhtin's theories, in order to make a case for considering applications of Bakhtin's theories to aid in reforming science education and improving student scientific literacy. To do so, the paper will begin with a detailed review of literature outlining Bakhtin's theories; present an overview of secondary sources that show how Bakhtin has historically been used to improve instructional methods, followed by a detailed analysis of the available studies that integrate Bakhtin's theories in the science classroom. By reviewing these sources, one can make arguments and suggestions for how science curriculum should be structured and summarize what implications Bakhtin's theories have for science education.

Background of Mikhail Bakhtin

Mikhail Mikhailovich Bakhtin belonged to a group of scholars in the early twentieth century who viewed language as something that always carried a social and cultural context (Marchenkova, 2005, p. 172). Bakhtin was born in Oryol, Russia to a liberal and educated family of old noble ancestry that encouraged his academic studies (Clark & Holquist, 1984, p. 16). As a youth, Bakhtin grew up in cities that had a clashing of unusually large amounts of diverse cultures and languages, a fact that no doubt influenced his future theories on the nature of language (Holquist, 2004, p. 1). After he graduated from university, Bakhtin ended up in small towns in the Soviet Empire, where he joined a circle of academics that met to discuss and debate philosophical, religious, or contemporary writings; the results of these discussions forever influencing Bakhtin's thinking for the duration of his lifetime (Clark & Holquist, 1984, pp. 38-39). While Bakhtin was a very active writer his entire life, it was not until after his death in 1975 that the academic world started paying attention to his writings, and their applicability to education (Holquist, 2004, p. 11). One of Bakhtin's overarching theories that pertain to the study of educational practice was that learning occurs through the dialogical processes and within "social learning spaces" (Zack & Graves, 2001, p. 235). Over time, many educational scholars began to use these theories to argue for a shift of teaching that focused on individual and internal learning, to that of interactions amongst learners (Marchenkova, 2005, p. 172). As this paper will critically review how these theories have been applied to education, it is imperative to briefly review some of Bakhtin's literary works from where these theories have been interpreted.

Theories of Bakhtin: Dialogue

In his writings on the *Bildungsroman*, Bakhtin attempted to categorize historical novels into four sub-categories based on the composition and development of the hero over the course of the story; the travel novel, the novel of ordeal, the biographical novel and the *Bildungsroman,* (Bakhtin, 1999, p. 10). What distinguishes the *Bildungsroman* from other literary forms is the journey and emergence of the hero in the novel, contrasted to other novel types where many heroes were presented as 'ready-made' (Bakhtin, 1999, pp. 20-21). In the novel of ordeal, the author did not depict the hero interacting with his world, something that Bakhtin felt made these heroes "unproductive and uncreative" within these novels (Bakhtin, 1999, p. 16). Within the *Bildungsroman*, that Bakhtin calls the "novel of education" or the "novel of becoming", however, Bakhtin noted that the hero is affected by their surroundings in a specific place and time, a *chronotope*, and the emergent hero grows along with his surroundings, and interacts with the emerging world (Bakhtin, 1999, p. 23). This description of the hero being unavoidably shaped by his or her surroundings, personified his unifying theories about language that permeated a great deal of his works, in which dialogic interactions always carry a cultural and social context, and dialogue is a key component to human existence (Marchenkova, 2005, p. 174). According to Bakhtin, all utterances in a language are dialogic in nature, as they contain not only the context of the person who spoke the utterance, but also the echoes of those who spoke the utterance previously (Marchenkova, 2005, p. 176). In other words, people do not create words within the language when they communicate, but rather they reinterpret the meanings and contexts presented to them in words previously, and repurpose them for their own communicative needs (Marchenkova, 2005, p. 176). "In short, in Bakhtin's concept of the dialogue, from studies of the novel, every utterance is itself a rejoinder, and our words are always half ours and half someone else's" (Weinstein & Broda, 2009b, p. 799).

Bakhtin also investigated the act of dialogue as a social process through his concept of *outsideness* as it relates to participants in a dialogue. From Bakhtin's perspective, for there to be genuine dialogue between two people, there needs to be a distinct perspective from one's self that differs from the other, or else the conversation would be monologic in nature (Marchenkova, 2005, p. 179). According to Bakhtin, it is our perspective that defines what we have to say in these dialogic interactions. As a result, it was also Bakhtin's belief that historical analysis of the culture that produced the text is always a must for a complete literary analysis, as the written text was dialogic in nature as well (Holquist, 1999, pp. 10-12). Bakhtin's theory of *heteroglossia* refers to this multitude of voices of languages, both social and national, that are present in everyday life and was defined through Bakhtin's analysis of dialogue within a novel (Vice, 1997, p. 18).

A character in the novel may engage in three forms of languages; the language that the character uses in conversations and inner-dialogue, the speech genre that exists at the moment of the utterance, and the cultural dialect and languages (Vice, 1997, p. 19). Therefore, Bakhtin postulated that in written works, there was always a dialogic conflict between the voice of the author, the voice of the character, and the social influences on both the author's and character's voice (Vice, 1997, p. 19). Bakhtin extended these theories about the written word, to describe real-life *heteroglossia*, which is defined as the mass of "informal and varied languages, dialects, and speech genres" (Vice, 1997, p. 20). Also, as with the written text, Bakhtin argued that all voices within the heteroglossia are equally full of intentions and importance; however, it is the dialogic conflict between the two that determines which one is expressed more clearly than the other (Vice, 1997, pp. 20-21).

While Bakhtin understood the basic function of language is to act as a 'code' so that humans can understand each other, he also believed that language was meaningless without its dialogic function, in which it creates meaning for those engaged in conversation (McCord, 1999, p. 3). In other words, Bakhtin did not subscribe to the theory that communication is a "one-way process," but rather both the speaker and listener played equal roles in the construction of meaning in the dialogue (McCord, 1999, p. 4). Since all written and oral discourse has an intended audience, Bakhtin also believed that all forms of communication are dialogic in nature (Zack & Graves, 2001, p. 231). Conversely, Bakhtin understood that monologic communication; where the listener is not receptive to the speaker's message, or the speaker does not internalize their own utterance, can never truly have meaning (McCord, 1999, p. 5). Through these ideas, Bakhtin was able to distinguish between *authoritative discourses*; language imposed on an individual in the discourse, and *internally persuasive discourses*, where those involved in the dialogue own the language and populate it with their own intentions (Lin & Luk, 2005, p. 94). Appropriately, Bakhtin believed a truly dialogic utterance directed at a listener or reader will always elicit a response – whether immediate or over time (McCord, 1999, p. 4). As an example, McCord (1999) contrasts the listener response to a military command, to that of a reader of a multi-chapter novel, in which the entire novel is essentially the writer's utterance (p. 5). While the listener feedback and action would be instantaneous with the military command and the reader of the novel would receive the utterance over a longer period of time, both would be given a chance to receive the author's/speaker's utterance and construct their own meaning as they are both involved dialogically (McCord, 1999, p. 5).

In an attempt to summarize and analyze Bakhtin's various works surrounding dialogue, many authors use Holquist's (2004) term of *dialogism* to refer holistically to Bakhtin's theories of conflicting utterances in a social context (Holquist, 2004, p. 15; Ewald, 1990, p. 1; Vice, 1997, p. 45). Fittingly for this review, Holquist compares Einstein's thought experiments involving relativity in order to explain the larger concept of dialogism. In paraphrasing the work and theories of Einstein around relative motion, Holquist notes that an object's motion can only be detected in relation to another outside observer's position. In other words, the motion can only be defined through its relative motion (Holquist, 2004, p. 20). By extension, Holquist argues that Bakhtin's theories of dialogism follow a similar nature, as the meaning of an utterance in a dialogue is defined by the outside observer, and the utterance is meaningless unless there is someone to construct meaning out of it (Holquist, 2004, p. 21). "The event of existence has the nature of dialogue in this sense; there is no word directed at no one" (Holquist, 2004, p. 27). In other words, according to Bakhtin, all language; spoken and written, is collaborative between the one speaking the utterance, and the person receiving the utterance (Ewald, 1990, p. 2).

Therefore, the act of language is not necessarily between two separate entities, but rather, two bodies interacting relative to each other (Holquist, 2004, p. 26). "Bakhtin's metaphor for the unity of the two elements constituting the relation of self and other is dialogue, the simultaneous unity of differences in the event of utterance" (Holquist, 2004, p. 36). Accordingly, Bakhtin placed a large emphasis on the role of the reader on the receiving end of the discourse between writer and reader (Ewald, 1990, p. 5). In a Bakhtinian sense, the meaning of spoken and written language is co-created by both the author, through the cultural system that produced the utterance, and the receiver, though the way they construct their own meaning of the utterance (Ewald, 1990, p. 4). Related to the concept of heteroglossia, this means that every utterance contains the neutral language of the words, the intention of the speaker, and the social and cultural context of the utterance, and that all three dimensions can be interpreted by the listener to make sense of the utterance (Vice, 1997, p. 45). As a result, Ewald (1990) argues that Bakhtin would believe that individual expression through discourse is not an expression of one's self, but rather a response to the audience of everyone else engaged in the dialogue around the topic at hand (p. 3). Thus, it is important to make the distinction that while heteroglossia is a "linguistic description" of the properties language can hold, dialogism is a "relational property" which allows for multiple perspectives and voices (Vice, 1997, p. 50). According to Bakhtin, "…it is only when we consider the dialogic function of language which permits disagreement and multiple voices that we can begin to understand the ways in which difference may serve as a thinking device" (Zack & Graves, 2001, p. 235).

Theories of Bakhtin: Carnival

As a metaphor for the opposing tensions in dialogue, Bakhtin also studied the festival of *carnival*, a celebration that blurred the lines between classes and cultural differences (Fecho & Botzakis, 2007, p. 553). The festival of carnival, though not celebrated to the same degree in modern times, was more than a simple holiday celebration, as the festival itself was celebrated in a time and space away from the fabric of society (Clark & Holquist, 1984, pp. 300-301). In the face of fierce political and social oppression, the celebration of carnival allowed a temporary escape where classes and hierarchies were obliterated, and the possibility of change was celebrated (Clark & Holquist, 1984, p. 301). In his works, Bakhtin (1984) noted about the celebration of carnival, that the festivities and playful mocking are deeply rooted in the lives of the participants, and that the rituals observed play an important role in the participants' actual lives, in contrast to other forms of entertainment, where there are performers and spectators:

> Carnival is not a spectacle seen by the people; they live in it, and everyone participates because its very idea embraces all the people. While carnival lasts, there is no other life outside it. During carnival time life is subject only to its laws, that is, the laws of its own freedom. It has a universal spirit; it is a special condition of the entire world, of the world's revival and renewal; in which all take part. Such is the essence of carnival, vividly felt by all its participants. (p. 7)

Through this, Bakhtin argues that laughter and the celebration of carnival was a fundamental, inseparable component of the participants' lives, not just an occasional festival that allowed them some escape (Bakhtin, 1984, p. 8). Due to this importance, it would be of no surprise that many large cities would dedicate months to these celebrations (Bakhtin, 1984, p. 13).

In well-known writings on the popular middle-ages writer, François Rabelais, Bakhtin investigated the culture of folk humor in the middle ages by analyzing the carnivalesque and *grotesque* qualities of Rabelais' work (Bakhtin, 1984, p. 4). Bakhtin felt that carnival not only existed in its own space and time, but the festival itself had its own set of language and language practices apparent in Rabelais' novels (Clark & Holquist, 1984, p. 304). By citing clowns and fools as common themes of Rabelais' novels, and a major recurring symbol of the culture of humor the middle ages, Bakhtin (1984) argues that understanding the seemingly juvenile aspect of the lives of these people who lived then, provides a tremendous amount of insight into their culture and the attitudes during the Renaissance (pp. 6-8). Bakhtin (1984) also noted a carnivalesque form of expression through Rabelais' work, notable for challenging established authority and hierarchies, another important part of the celebration of carnival (p. 10). In contrast to everyday life, and even official church-sponsored events, all participants of the carnival festivities were considered equal, regardless of status or class (Bakhtin, 1984, p. 10). Under these circumstances, all people were able to communicate freely and form human connections amongst each other (Bakhtin, 1984, p. 10). Without the usual restrictions on speech and actions that made these interactions impossible, people were able to speak frankly, engage in authority-questioning discourse, and share common experiences – all through this surreal suspension of time and place (Bakhtin, 1984, p. 10).

Another recurring theme that was of interest to Bakhtin is the sense of grotesque realism that permeated Rabelais' work (Bakhtin, 1984, p. 18). Much of Rabelais' work contained embellished depictions of the human body and bodily functions that earned him as much praise as it did criticism (Bakhtin, 1984, p. 18). Bakhtin (1984) contends that Rabelais' purpose in evoking these images in his novels was to degrade what was held as spiritual and abstract to mundane and common (p. 19). In addition, as the festival of carnival was essentially a festival of change, portraying grotesque bodily functions undergoing changes, (i.e. the digestive process), furthered the spirit of emergence through carnival (Clark & Holquist, 1984, p. 303). Rabelais also reveled in depicting sex and bodily functions that portrayed humans as animals, a taboo theme for his time, which Bakhtin referred to as 'grotesque realism' (Clark & Holquist, 1984, p. 312). Bakhtin believed that the expression of the grotesque in Rabelais' work was the embodiment of the spirit of carnival itself (Clark & Holquist, 1984, p. 312).

Bakhtin's broad theories of the carnivalesque and grotesque realism, along with his theories of heteroglossia and dialogism are the subjects of this literature review, and more specifically how they have been applied to the world of modern education. All of these theories have a common underlying theme of language in a social context, and how learning can occur through dialogic interactions. Given the nature of these theories, involving oral and written communication, there is a great deal of research available on Bakhtin's theories as they apply to literature, reading, writing, social studies, and foreign language classroom instruction. The following section will review some of this available research to demonstrate how Bakhtin's theories around learning through dialogic interaction have been used to improve general classroom instruction across multiple subject areas, followed by studies that exhibit applications of Bakhtin in the science classroom.

Applications of Bakhtinian Dialogue in the Classroom

In reviewing studies that involve using classroom dialogic interactions, there are many secondary sources that directly reference the role of dialogue in the Bakhtinian sense. For instance, Kubli (2005) explicitly states that Bakhtin's theory of dialogism can be used as a pedagogical tool because of its underlying definition that states consciousness and knowledge are based on exchanging ideas with others (p. 504). This is because within the context of Bakhtin's heteroglossia, all voices in the dialogue are a product of their social context and are equally important to the learning process in the classroom (Fecho & Botzakis, 2007, p. 553). Therefore, Kubli (2005) believes that it is critical that the teacher be cognizant of each student's input to the dialogue and how they are constructing meaning of the situation (p. 508). Understanding the perspective of the audience, in this case is the students, is crucial for effective communication. Otherwise, the teacher will address the class as an abstract idea and not as individual students with individual interlocutors, or unique participants in the conversation (Kubli, 2005, pp. 509-510). As a result, when students feel disconnected to content, that is when they cannot make meaning of the situation in a classroom setting or they cannot formulate an appropriate response to the teacher, these students will become disengaged and the learning will be lost on them (Kubli, 2005, p. 507). This reflects Bakhtin's notion that an utterance's meaning is negated if there is no one to receive it and construct meaning (Holquist, 2004, p. 21).

There are studies that describe situations where teachers neglect student voices in a Bakhtinian sense within the classroom dialogue. Hamston (2006) investigated the role that discourse and multiple social voices had on a cultural diversity project in an Australian classroom. According to the researcher, years of racial, lingual and cultural dominance from European-descended Australians had left many Australians of Asian descent and indigenous Australians questioning their own identities as Australians, leading to a resistance to learn about Australian history and culture (Hamston, 2006, p. 57). In order for these individuals to be truly engaged in dialogue beyond simple language exchange, the various social voices, or the heteroglossia, must equally contribute to the discourse exchange (Hamston, 2006, p. 57). Furthermore, Hamston (2006) suggests by having students engaging in dialogue about cultural differences from their own perspectives, students can truly gain empathy for others, and also in turn, face their own 'ideological becoming' (p. 58). In order to test these theories, Hamston (2006) observed students from different racial, ethnic, and cultural backgrounds to discuss sensitive topics, such as "Who is an Australian?" and a debate about Australia's geographic classification in the Asian region, while the students' responses and body language were recorded (p. 62). Through these conversations, all students were able to internalize their own views on these topics, share their inner-monologue with the group, and ensure their ability to think and share critically to the cultural dialogue of these issues in future conversations in their daily life (Hamston, 2006, p. 70).

Another study done by Lin and Luk (2005), demonstrates the role that Bakhtin's theories around dialogue play in an English language learning classroom in Hong Kong. In this class, students are expected to learn English and standard Chinese before mastering their own native language, Cantonese, which in turn affects their perception of how they value themselves and their attitudes towards learning English (Lin & Luk, 2005, p. 82). Similar to the study performed by Hamston (2006), students who did not belong in the dominant cultural group were not able to contribute to the dialogue because they were not able to construct their own meaning out of the material. In other words, many students could not construct meaning out of the teacher's utterance, because of cultural or linguistic differences, and therefore, the student was left out of the learning process. These studies suggest that by constructing curricular activities that ensure all students can relate to and contribute to the classroom dialogue; teachers will be more effective in keeping the students' attention.

Fecho and Botzakis (2007) applied Bakhtin's idea of heteroglossia in the classroom, and argued that an equal emphasis should not only be placed on the students' background and perspective, but on that of the teacher and the textbook (p. 553). In a truly dialogic classroom, the teacher must possess the ability to create and learn along with the students in order for true cognitive development to be possible (Fecho & Botzakis, 2007, p. 551). Similarly, motivated by Bakhtin's theories of two-way dialogic communication (p. 4), Delahunty (1989) investigated the negative impact that low-level knowledge transmission from teacher to student plays in the classroom, and the reasons why teachers use these methods. Through observations in community college classrooms, Delahunty exposed growing trends in education, ones that require students only to produce information when given specific cues, as detrimental processes to the ability for students to engage in written and spoken discourse (Delahunty, 1989, p. 4).

One of the major reasons for this shift is that the role of the instructor has shifted to authoritative viewpoint, and the classroom must shift back to that of a "mutual cognitive environment" where the single intention is to collectively reach an understanding (Delahunty, 1989, p. 17). From Bakhtin's perspective, many teachers have adopted an authoritative discourse approach in their classes, but to be effective, students must engage in internally persuasive discourses where they can take ownership in the learning process (Lin & Luk, 2005, p. 94). To shift to a more collective learning environment, teachers must reconnect with themselves as a learner and rediscover the learning process. This will allow the teacher to truly engage with their own students who are simultaneously embarking on the same process (Delahunty, 1989, p. 17).

To demonstrate how meaning can be constructed collectively between the teacher and students, Miller (2003) applied Bakhtin's theories to investigate the effects of literature discussion in the learning process, and how engaging in classroom dialogue between peers, teachers, and texts, students can learn how to engage in 'larger cultural conversations about interpretations and possible meanings (p. 289). By engaging students in classroom discussion, students will be exposed to 'new social languages and meaning-making strategies' while improving students' 'self-conscious reflection' (Miller, 2003, p. 290). In a series of reported observations from a high-school literature class engaged in a discussion involving a literary text, Miller reported students asking authentic questions, and being active participants in a productive conversation (Miller, 2003, p. 293). Eventually, as the students gained more practice in being engaged in meaningful dialogue with their peers, even the tone of their questions shifted from argumentative to supportive (Miller, 2003, p. 294). As Miller (2003) notes, the students began "talking with each other" rather than "talking at each other" (p. 294). However, to emphasize how important the teacher's role is in cultivating a classroom atmosphere that supports student questioning and discussion, Miller (2003) contrasts this classroom with another teacher who did not consistently provide students with support and mediate the conversation appropriately, and the low buy-in from the students as a result (pp. 294-295). At the end of her series of studies, Miller (2003) determined that a 'teacher-mediated open-forum discussion' where students and the teacher were collaboratively understanding together helped students better understand the text (Miller, p. 312). Additionally, students who participated in these open-forum discussions started to see their peers as a collaborative learning community over time, and found confidence in expressing their own voice in the discussion (Miller, 2003, p. 312).

In another study done on collective learning through dialogue, Zack and Graves (2001) utilized the applications of Bakhtin's theory to construct a dialogic mathematics classroom, and to observe how students interdependently constructed knowledge in a social setting. The subject of mathematics has a deeply ingrained stigma of how a mathematics classroom should be structured. This traditionally consists of a transfer of math facts and drill practice, with rarely the chance to talk and argue about mathematics. Dialogically-structured math classrooms are so rare that most students need to be trained how to participate in dialogic activities (Zack & Graves, 2001, p. 236). Based on this assumption, the teacher in this study set up the lessons so that students worked on non-traditional problem solving; first through working independently in their math logs, and then working interdependently with students in the classroom. As an ongoing assignment, students were given a series of more challenging questions to solve within this format, and student dialogue was observed to demonstrate how differences in opinions and voices can be used as a learning device (Zack & Graves, 2001, p. 235). When the students became stuck on a challenging problem, they used their group time to discuss what methods they have tried to use and what was confusing them. Through this process, they learned from each other and made meaning collectively until they eventually solved the problem (Zack & Graves, 2001, p. 256). In addition to stimulating their communication skills, Zack and Graves (2001) note the benefit of having students discuss mathematics, in that it is impossible for students to truly understand a concept if they cannot explain how it works (p. 253).

What is important to note in both the studies done by Zack and Graves (2001) and Miller (2003), was that the teachers were not successful simply because students were engaged in conversation. Rather, these students were collectively making meaning with each other using the teacher, the text, and their peers as scaffolds. In order to demonstrate the difference between what he refers to as “pedagogical dialogue” and “dialogical pedagogy,” Skidmore (1999) details two different examples of classroom discussion where students were required to discuss the text they had read. Skidmore (1999) defines “pedagogical dialogue” as teacher-dominated control of the discussion that trends towards monologistic, as the teacher is the authoritative voice who possesses the ‘correct’ answer to give the student (p. 10). In his example, an elementary school teacher asks a student to recall information in a text, and when the student does so incorrectly, the teacher corrects the student and directs the class to look for the “correct” answer in the textbook. While the teacher defends her actions claiming that it is showing students how to find information in the text, Skidmore (1999) argues that she has missed a crucial teachable moment where the discussion could have been turned to the class for their responses to the student’s answer (p. 11). In both the example given by Skidmore (1999) and the second example provided by Miller (2003), the teachers achieved less-than-desired results and low student buy-in because the lesson was teacher-focused and the teachers did not mediate the conversation appropriately.

Conversely, to demonstrate the key differences between “pedagogical dialogue” and “dialogic pedagogy,” Skidmore (1999) recounts a different classroom engaged a collaborative discourse about a text they just read, where they are asked to summarize and give evaluative descriptions about what they read in their own words. In this classroom, the dialogue is student-centered and driven, distinguishable by the building of students' ideas upon one another, and where the teacher largely acts as the facilitator (Skidmore, 1999, p. 15). In a Bakhtinian sense, this exercise also forced students to construct their own meaning, or engage in internally persuasive discourse (Skidmore, 1999, p. 16). Skidmore (1999) states:

> At certain pivotal moments during teacher-student dialogue, the lead offered by the teacher can have real and educationally significant consequences for the course of the subsequent talk: it may tend to retrace the familiar certitudes of authoritative, teacher-controlled discourse; or it may invite students to engage in the riskier, more taxing, but more fulfilling enterprise of formulating and being answerable for their own thinking. (p. 20)

Furthermore, Skidmore argues that for a "critical understanding and appreciation of literary texts" it is crucial that teachers approach this in a non-algorithmic, knowledge-recall manner (Skidmore, 1999, p. 18). This example of "dialogic pedagogy" echoes the successful teachers seen in the Zack and Graves (2001) and the Miller (2003) studies, who all engineered learning environments were students and teachers collectively made meaning through social discourse.

In addition to views on oral discourse, Bakhtin felt that written communication was dialogical in nature as well (Holquist, 1999, pp. 10-12). Building on these theories from Bakhtin, Majidi (2005) surveyed students beginning college to determine how they perceived academic writing as a form of academic discourse, and how they perceived their roles as part of the academic community. Majidi's (2005) research showed that in fact, students did not view themselves as contributors to the academic dialogue through their writing, and more often;

students reproduced others' knowledge instead of producing their own demonstration of learning (pp. 10-12). One of the reasons for this, Majidi (2005) argues, is that students reported their difficulty in conceptualizing an audience other than their professors (p. 2). Majidi (2005) points to Bakhtin's theories around discourse communities, and recommends that students have social motivation to write that goes beyond reproducing information to their teacher for a grade (p. 5). As a result of this study, Majidi (2005) advocates for a community of readers for students papers, perhaps through 'published papers' that could be kept in libraries or shared among classes, so students can feel they are contributing to the larger discourse community and feel more confidence in academic writing (p. 16). Just like the studies that investigated oral discourse as pedagogical tools, the success of written discourse in educational settings depends on the teacher's ability to construct an authentic dialogical classroom.

Applications of Carnival in the Classroom

As there are available research studies that apply Bakhtin's theories of dialogue to learning and instruction, there are also studies that apply Bakhtin's theories about the celebration of carnival and the grotesque as pedagogical tools to promote joy and laughter in the classroom. DaSilva Iddings and McCafferty (2007) researched how a group of young English-as-a-Second Language learners overcame internal obstacles preventing their completion of an assignment by re-creating the context of the assignment through the spirit of Bakhtin's carnival (p. 31). While the students seemed off-task by communicating in a playful and comical manner, the researchers noted that this was the only time the students completed the original task of speaking English with authenticity (DaSilva Iddings & McCafferty, 2007, p. 34). In another study performed by Lin and Luk (2005), English learners were directed to repeat the teacher's English statements as a means of practicing, but instead, the students slipped into a state of carnivalesque playful mocking when repeating it back, intending to challenge authority in order to populate the utterance with their own voice (Lin & Luk, 2005, p. 86). Other studies support these findings, as language play can even help adult language learners connect their old familiar language with the new language they are learning (DaSilva Iddings & McCafferty, 2007, p. 33). These studies suggest that the teacher should construct learning opportunities that engage students in "internally persuasive dialogues of interest to students so that English can become a language populated with students' own voices and become a tool that students can use to construct their own preferred worlds, preferred identities, and preferred voices" (Lin & Luk, 2005, p. 92).

In addition to the obvious engagement in a state of play, observable by laughter and word play, there are studies that demonstrate how teachers and students can embrace the grotesque and grotesque realism in the Bakhtinian sense. For example, the young English Language Learners in the study done by DaSilva Iddings and McCafferty (2007) were observed assigning and swapping animal and human characteristics and parodying situations that involved death, sickness, and relationships during their language play (p. 41). In other observed examples, students demonstrated embracing of the grotesque, through indecent English dialogue, and other carnivalesque behaviors, such as mutating classroom dialogue from boring and alien, to familiar and fantasy-like (Lin & Luk, 2005, p. 92). McKenzie (2005) also analyzed various works in children's literature that exemplified Bakhtin's ideas of carnivalesque and grotesque content, which happen to be quite popular with students, and disliked by many teachers. McKenzie (2005) claims that since children are given so little control over their lives in the face of adult authority, books filled with grotesque humor and that challenge social hierarchies allow students to temporarily escape the rigid structure of their lives (p. 84). The embracing of the grotesque and the spirit of carnival demonstrated by students in these examples parallels Bakhtin's description of those who celebrated in carnival in the past. Just as the festival participants in the middle ages, the behavior of the students in these examples demonstrates an inherent human trait to challenge authority when faced with opposition.

Since Bakhtin envisioned carnival as a "form of rejuvenation achieved through the playful mocking of the hierarchical order by individuals who find themselves oppressed by it," (DaSilva Iddings & McCafferty, 2007, p. 31), the teacher must be especially aware of their role in facilitating a state of carnival in the classroom. Entering a state of carnival is a dialogic experience just as facilitating a dialogue in the classroom, and therefore the importance of the teacher's tolerance of students' actions helps students feel comfortable entering a state of carnival (DaSilva Iddings & McCafferty, 2007, p. 41). Since the state of carnivalesque play in the classroom results organically from student rebellion against the hierarchy in place, teachers should not attempt to force students into this state, but rather nurture learning environments and activities that encourage this behavior without disrupting the overall learning of the classroom (DaSilva Iddings & McCafferty, 2007, p. 42). Even though teachers may feel uncomfortable with exposing students to grotesque elements, especially when carnivalesque behavior challenges the teacher/student relationship, the shared, common experience between teacher and student that arise from this aspect of play is necessary to be effective (McKenzie, 2005, p. 87). Just as important as the teacher's role in facilitating dialogue, the teacher must also strive to facilitate activities that support controlled moments of carnival that students perceive to be constructed on their own.

Criticisms of Bakhtinian Applications

The studies discussed so far have shown the benefits of applying Bakhtinian theory to the classroom; however, there are also studies that investigate negative effects of implementing dialogic pedagogy in the classroom. In the light of a growing trend of implementing group interaction in the classroom, Tochon (1998) investigated the potential for 'Bakhtinian Plagiarism' and the possibility for negative interdependence among the peer groups that comes from borrowing ideas in an improperly structured group learning environment. Tochon (1998) approaches this subject with the acknowledgement that the cognitive benefits of collaborative learning are valid reasons for using this approach, nonetheless, he feels that teachers must diligently monitor the interpersonal relations between students to avoid intense conflict among students for the entire school year (p. 7). In order to build "positive interdependence," where students recognize that they are mutually responsible for learning, the group must share common goals, outcomes, and motivating factors (Tochon, 1998, p. 9). Additionally, with using collaborative learning groups, teachers have to overcome social factors, cliques, and students who actively seek out ways to not participate when working in small groups (Tochon, 1998, p. 10).

Over the course of his study, Tochon (1998) observed students in multiple classes working in small groups to complete a creative assignment in where each group was to come up with a short dialogue to present to the class. The results showed that not only did every group "borrow" ideas, either from listening in on other groups or by checking in with a teacher to borrow their ideas, but the groups reacted strongly if the borrowing affected their group positively or negatively (Tochon, 1998, pp. 20-21). However, even though many ideas were mutually shared amongst groups to the extent that the sources of the ideas become unidentifiable, groups still were vocal about which ideas were their own, and which groups “borrowed” them from them (Tochon, 1998, pp. 20-21). Driving this ‘negative interdependence’ in the classroom were the underlying attitudes of students towards borrowing ideas, essentially being viewed as cheating, and the class was not structured to value other students as part of one’s own cognitive development (Tochon, 1998, p. 21). Overall, Tochon (1998) found that “borrowing” and “plagiarism” are necessary evils of constructive learning, but they can have extremely positive effects on creativity and the learning process only if students collectively acknowledge their academic goals, as well as the role that borrowing ideas from others plays in collaborative learning (p. 31). However, it should be noted that in defining the negatives of collaborative learning, it is acknowledged that the ability of the teacher to effectively construct a learning environment that encourages collaboration is detrimental to whether or not these lessons are effective.

Multiple studies discussed thus far have highlighted the importance of teacher facilitation of genuine dialogic classrooms versus engaging in simple conversation. However, other criticisms of applications of Bakhtin’s theories arise from the questioning of the ability of teacher to truly engage the class in genuine dialogue without appropriate training and background. Zack and Graves (2001) note that the teacher must be able to take the conversation beyond a traditional classroom conversation, and nurture a learning environment that encourages student discussion and argumentation (p. 258). This can be structured by creating learning opportunities that explicitly require these tasks, as well as the approaches that the teachers use to communicate classroom expectations and conduct. In Zack and Graves’ (2001) study, the teacher is cognizant to assure students that building off each other’s ideas is encouraged, and even gives credit to students who contribute to the dialogue by naming the methods and processes in the solution after the students that identified them (p. 259). Teachers should not restrict dialogue started by students, even at the expense of covering material in lectures, as Bakhtin would believe these students are possibly trying to construct their own understanding of the concept (Fecho & Botzakis, 2007, pp. 548-549). Instead, teachers should also facilitate dialogue in spoken and written forms in order for students to make sense of new concepts, and allow students to challenge authoritative views through discussion or play (Fecho & Botzakis, 2007, pp.548-549). As important as the teacher is in facilitating this type of classroom, the authors note that it is hard to replicate these types of classes because, “teachers are themselves products of the very system they now aim to change,” and do not have models to structure their classroom after (Zack & Graves, 201, p. 234).

While not studying the applications of Bakhtin explicitly, Leonard (1999) may have identified a potential solution to this ongoing problem while studying teacher candidates in a math teacher preparation program. In order to improve their classroom dialogue facilitation abilities, teacher candidates participated in dialogic discussions during their teaching methods course, while its effects on their ability to facilitate discussion-based learning in their respective classrooms were observed. Leonard (1999) cites many other studies that highlight the fact that the majority of traditionally-taught mathematics classrooms perpetuate the “teacher-questioning, student-answering, and teacher-evaluating” cycle, and the most important factor in breaking this cycle is the facilitation of genuine dialogue by the teacher (p. 5). Referencing studies that prove the level of student interaction has a strong positive correlation with student academic achievement, Leonard (1999) concludes that creating opportunities that truly engage students in meaningful dialogue is a necessity for reforming mathematics instruction, and teachers will only be able to do this with the appropriate training and exposure to discourse in learning (p. 17). As stated previously, in a truly dialogic classroom, teachers should learn as much from the students, as the students learn from the teachers (Zack & Graves, 2001, p. 234).

Applications of Bakhtinian Dialogue for Science Education

The studies mentioned thus far are just a small percentage of the educational practices and applications that have been accumulated through analysis of Bakhtin's theories. Given the communicative nature of these concepts, it is understandable that the majority of educational uses for Bakhtin fall within the realm of literature, writing, foreign languages, and other arts; without a major emphasis on the hard sciences. Nevertheless, there is an increase in the number of studies that argue for integrating dialogic pedagogy into the science classroom to improve student performance in science. The following section provides an extensive review of available research and writings of science classroom applications that both reference Bakhtin as inspiration explicitly, and some that reference the notion of dialogic interaction as a pedagogical tool. These studies will be presented in order to draw conclusions about how science curriculum should be designed, and to identify implications for further research on Bakhtin in the science classroom.

According to the National Science Education Standards, one of the major goals of science education is that of developing scientific literacy. 'Scientific literacy' is defined as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (NSES, 1996). However, Lemke (1993) contends that students in traditionally taught science classrooms never receive scientific literacy instruction and never actually encounter 'science' in their science classrooms, as students "never meet a scientist, never observe science being done in the laboratory or the workplace, never see samples of professional scientific or technical writing, never hear the language of science in use for its normal social functions, never come into contact with the equipment, processes, practices, and social and economic realities of science as a human activity" (Lemke, 1993, p. 1). Instead of learning from engaging in dialogue with the scientific community, science teachers and textbooks acts as authoritative keepers of knowledge (Lemke, 1993, p. 1). Furthermore, by isolating students from studying science through a social context, teachers are depriving students from the very nature of the subject at hand. Concepts such as heat, magnetism, energy, and light are abstractions that have meaning only through human observation, description, and cultural interchange of experiences with these phenomena (Lemke, 1993, p. 4).

In agreement, Osborne (2007) asserts that to receive a complete science education and training in scientific literacy, the instruction should consist of four components:

> The conceptual which builds students understanding of the knowledge and ideas of science; the cognitive which attempts to develop students' ability to reason critically in a scientific manner; …the processes, values and implications of scientific knowledge; and the social and affective which attempts to develop students ability to work collaboratively and to offer an engaging and stimulating experience. (p. 177)

The last of these components, he argues, renders the other components invalid if teachers are not able to address the social aspect of science education, that which views scientific knowledge as something that is developed through dialogue and discourse (Osborne, 2007, p. 180). Based on the theories that scientific knowledge arises from community discourse and language is the main tool for those engaged in said discourse, Kelly (2007) postulates that language is a key component for the creation and communication of scientific knowledge (p. 47). While this would seem to argue for an increased focus on student mastery over the scientific language to achieve scientific literacy, Kelly (2007) notes that scientific literacy is more complex than just being able to write and read science (pp. 47-48). He distinguishes between ‘fundamental science literacy’ as the ability to read and write about scientific topics, and ‘derived scientific literacy’ as being truly knowledgeable in the content area (Kelly, 2007, p. 48). Correctly gaining scientific literacy, Kelly argues, is deeply rooted in social interactions. “First, learning literate practices in a fundamental sense entails acculturation to a broader set of ways of speaking, acting, and being in the world. Second, these acculturations involves the communication, and thus privileging, of some(one’s) knowledge” (Kelly, 2007, p. 48). Consequently, this act of gaining scientific literacy parallels Bakhtin’s theories of how any language is acquired, through dialogic interactions with others.

Osborne (2007) believes that in the science classroom, just as with other subject areas, dialogic interaction should be used for students to construct meaning, and should play a central role in defining scientific knowledge and processes for students (p. 180). By integrating opportunities for scientific discourse in the science classroom, students receive exposure to others’ point of view, which in turn helps them construct their own scientific knowledge (Kelly, 2007, p. 48). In fact, research supports that the absence of discussion of ideas and exploration in the classroom were among major reasons for low student performance and dislike of the sciences (Osborne, 2007, p. 180). Unfortunately, many science teachers in traditionally-taught science classrooms report that student dialogue and classroom discourse were techniques rarely used in their classrooms (Osborne, 2007, p. 181). Teacher ability appears to be the biggest indicators of using dialogic pedagogy, as teachers who are confident in their understanding of science facilitate the learning process through authentic, dialogic, student-directed activities; whereas teachers who lack confidence tend to lead closed, authoritative, and inauthentic learning activities (Osborne, 2007, p. 181). As seen previously in Skidmore's (1999) distinctions between 'pedagogical dialogue' and 'dialogic pedagogy', teachers need to distinguish between conversations about science and actually engaging in scientific dialogue to be effective.

Lemke (1990) differentiates between 'pedagogical dialogue' and 'dialogic pedagogy' in the science classroom by defining it as 'talking science,' as opposed to 'talking about science'. Rather, "talking science" is the process of "doing science through the medium of language" whereas language is "a system of resources for making meaning" (Lemke, 1990, p. ix). Lemke (1990) believes that to learn how to talk science, students must learn how to communicate as a member of the scientific community, and they learn this process through speaking with those who have already achieved mastery (p. 1). The process of talking science with another person, which includes causal statements supported by data-backed arguments, is so unnatural for so many students that it is almost like a foreign language for them, making scientific dialogue in the classroom challenging (Tabak & Reiser, 1999, p. 10). Contributing to the difficulty of mastery of the language of science, Lemke (1990) argues, are the structure that the written and oral communication takes, and the relationships between abstract concepts and how these concepts fit together into thematic patterns (p. 21). He continues to argue that there is a great deal of talk *about* science in the classroom, but very little 'science talk' because students are never explicitly taught the linguistic skills necessary (Lemke, 1990, p. 22). Nevertheless, since the ability to talk science is necessary for a student to achieve scientific literacy, teachers must implement activities that encourage scientific discourse in the classroom (Tabak & Reiser, 1999, p. 10).

Therefore, teachers must find ways to foster dialogic communication in the classroom, and construct learning opportunities that help students develop these skills. Tabak and Reiser

(1999) argue that manufacturing "extended student-directed investigation activities, where students grapple with scientific questions, marshal primary data and construct explanations, can act as a catalyst and provide important fodder for students' science talk" (p. 18). Another effective method of engaging the class in scientific dialogue is referred to as 'joint construction', a process that the teacher facilitates, consisting of helping students construct meaning by providing prompts, restating the driving question, and synthesizing the input from the classroom (Tabak & Reiser, 1999, p. 18). In addition, teachers and textbooks come to the classroom with the knowledge of proper usage of scientific language, while students do not. More often, they will have some sort of experience with scientific concepts from their everyday lives – albeit many times with misconceptions attached (Lemke, 1990, p. 27). Hence, one of the main goals of science education should be "to provide students with new ways of talking about scientific concepts" (Lemke, 1990, p .27).

Understanding why it necessary to treat the 'language of science' as a separate linguistic body is clearer when viewed through the lens of Bakhtin's philosophy of a social language, where language is "a symbolic system of resources for communication to the realization of a conception in which language is constitutive of identities, or relationships between subjects and of relationships between subjects, institutions, and knowledge (Martins, 2007, p. 56). In her definition of the language of science as a social language in the Bakhtinian sense, Martins (2007) claims that science is a socially constructed body of knowledge, created to describe the 'human experience' (p. 57). In other words, the utterances that comprise the ways of thinking and talking about the world, that have been created within the scientific community, fit within Bakhtin's definition of a 'social language' (Leach & Scott, 2003, p. 99). This 'scientific social language,' differentiates everyday communication with the speech patterns and processes that make up communication in the science lab and the science classroom (Leach & Scott, 2003, p. 100). In addition to the ability to verbalize scientific concepts to construct meaning, students with a familiarity with the body of knowledge of science can become more engaged in social and political dialogue about the applications of this knowledge (Martins, 2007, p. 59). Without an appreciation of science, Martins (2007) argues that a student would not be able to effectively participate in democratic dialogues regarding stem cell research, global warming, genetically mutated crops, and the HIV/AIDS epidemic (p. 59). Therefore, Leach and Scott (2003) propose that the process of learning science should be analogous to that of learning to talk science (p. 101). Still, the learning process is not as a simple transfer of information through conversation. The role of the teacher in guiding classroom discourse and dialogic interactions is a key component to effective student learning (Leach & Scott, 2003, p. 105).

The concept of an academic language as a ‘social language’ is not exclusive to the sciences alone. Just as people learn to use different social languages in different social settings, which can include “grammatical features” and differentiated styles, many academic languages are necessary for students to master in order to be successful in school (Gee, 2005, p. 20). Gee (2005) believes that science can be particularly difficult for students to grasp due to the large amounts of abstract symbols, unfamiliar vocabulary, and accepted practices that are alien to students without extensive scientific knowledge (p. 19). In addition, there are numerous conflicts with the students’ familiar language and culture that prohibits students from fluently engaging in the social language of science. Learning the scientific academic language is a crucial component that determines a student’s success in science, but nonetheless, many instructional methods involving the language of science are ignored by teachers (Gee, 2005, pp. 19-20). Leach and Scott (2003) reason that “the development of scientific knowledge is not only constrained by empirical data, but is also socially validated by the scientific community," and thus, learning in the science classroom should be socially constructed as well (p. 91). In other words, as scientists communicate their findings through publishing in reports and journals, and use the ongoing dialogue with the rest of the scientific community to further their understanding of natural phenomena; students in the science classroom should mimic these roles.

One illustration of the challenges raised by scientific vocabulary involves an example where a teacher and a student debate about how to define the abstract concepts of light and heat. During the argument, the teacher takes the accepted stance from the scientific community, while the student uses his own personal experiences to construct his own explanation. Lemke (1990) notes that in this debate, there is a double conflict – one involving the linguistic conflict between each participant's semantics, and the social conflict between teacher and student (p. 32). When discussing the Law of Conservation of Energy, the teacher tries to explain to students that light energy can be converted to heat energy, while a student challenges his theory and makes the claim that light is hot, so therefore, light is the same as heat (Lemke, 1990, p. 28). What drives this conflict of semantics is that the student has a different thematic pattern than teacher for how to describe forms of energy. However, instead of giving the student a chance to build on his argument and allow for true discourse, the teacher uses his authority to provide the 'correct' answer and stop the student from making sense of the material (Lemke, 1990, p. 29). By not providing a platform for the student to engage in meaning-constructing dialogue, Lemke (1990) states that the teacher effectively turned the conversation into a monologue (p. 31).

In addition to inadvertently limiting the amount of genuine classroom scientific dialogue, many teachers are unaware of the effect that their word choice and phrasing plays on student perception of the language of science (Liberg, Geijerstam, & Folkeryd, 2007, p. 45). Compared to other academic subjects, discussing science requires students to use a vocabulary set that is full of generalizations, abstractions, and technical terms, as well as a language style different from everyday speech (Liberg et al., 2007, p. 44). Furthermore, Liberg et al. (2007) note that many scientific terms are 'dense' with meaning, and come with a specific connotation (p. 44). One example of this is the term 'solar eclipse', when compared to the phrase, 'the sun gets dark.' Saying that 'the sun gets dark' during a solar eclipse is misleading, as the cause is the moon passing in front of the sun, and does not completely explain the phenomenon as the term 'solar eclipse' does in a concise manner (Liberg et al., 2007, p. 44). On the other hand, without hearing the description in everyday terms, many students may not get the concept because they are not familiar with the technical terms (Liberg et al., 2007, p. 44). In fact, a blend of everyday and scientific language is best to ensure students are able to move from the concrete to abstract definitions, without alienating students who would otherwise not understand the scientific definition (Liberg, et al, 2007, p. 44).

In his writings on the topics of these conflicting languages and their effect on learning in the science classroom, Roth (2005) describes the act of learning how to talk about science as a paradoxical situation. Roth (2005) claims that "meaning is the dialectical relation of sense and reference," and that sense and reference cannot be independently developed (p. 149). When students learned the language of their everyday life, the language was neither about the world nor what the world was like, but rather they learned language to make their own sense of their surroundings (Roth, 2005, p. 150). Therefore, in order to learn how to use the language of science, students need to be placed in meaning-making activities where they can draw on the "linguistic resources" of others who are fluent in science (Roth, 2005, p. 150). In other words, Roth (2005) argues that teaching is a mediating activity that allows students to understand and use words that normally would not be inherently known by simply hearing them (p. 150). However, it is within in the closed system of the classroom where students eventually learn to articulate the scientific world, and it appears to have been a co-evolution between the teacher and the students (Roth, 2005, p. 150). According to Roth (2005), in order for students to truly engage in a knowledgeable conversation about science, the most important component is that the students find their own voices and intentions, as Bakhtin envisioned, in the language of science (p. 172).

To demonstrate his point, Roth (2005) studied conversations held in small groups of students in his science classrooms and showed how their attempts at explaining a new situation resulted in an emergence of a new way of talking (p. 151). In this classroom, students were instructed to manipulate force and velocity parameters on a computer simulation to get a ball to follow a desired path. In recording these conversations, Roth (2005) observed the students using their own language and terms to collectively describe a new situation presented in the simulation that conflicted with their real-world experiences (p. 168). As the ball required a force that counteracted the downward pull of gravity, students began to refer to the upward force as "antigravity" in their group, using conventions of the English language in order to collectively explain the occurrence (Roth, 2005, p. 169). Other students used slang such as "whatever" and "doohickey" to communicate unknown scientific terms with other members of the group, and explained the object's change in velocity as the moment when "gravity kicks in" (Roth, 2005, pp. 170-171). By joining groups and contributing limited amounts of "language elements" to the students' conversations, Roth (2005) was able to provide the students with the linguistic tools necessary to integrate scientific language into their own ways of talking (p. 172).

In reflecting on his experience, Roth (2005) pointed out the importance of starting teacher-student interactions in a way that reflected the students' own way of talking, before introducing these new "language elements" (p. 172). On the importance of this alignment between teacher and student, Roth (2005) states:

> In the science classroom (just as in any other social situation), students and teachers may use the same ways of talking. But unless they are attending to and are perpetually attuned to the same entities in the same way, there is a vast amount of room for misunderstanding that may never be detected; or teachers and students may be attuned to the same global things, but attend to them in different ways – such as when interlocutors are talking about a graph, but they are attuned to its height and slope, respectively. Thus, a crucial aspect in teaching (science) is that students and teacher focus on, and are attuned to; the same thing in the same way…The transfer of descriptive and explanatory language from one to the other situation mediated the articulation. This transfer itself occurred in language that was therefore not about the world but had as its major function the evolution and constitution of this language. (p. 166)

Roth (2005) reasons that both language and teaching are mediators between students and the world. In many traditionally-taught science classrooms, the teacher is able to draw on experiences with the world and the language of science, while the students have none of the above experience (Roth, 2005, p. 173). As a result, teachers must develop curricular strategies that expose students to natural phenomena, while using their own native language as a scaffold to build student familiarity with the language of science (Roth, 2005, p. 174).

Opposed to the intermixing of scientific and everyday language, Gee (2005) expresses the concerns around its potential interference with student learning of the scientific academic language. By engaging in the language of science, students lose part of their own language identity through how they speak in the "lifeworld." For example, a student's organic observation to an experiment would be stated as, "Hornworms sure vary a lot in how well they grow," versus the more scientifically appropriate, "Hornworm growth exhibits a significant amount of variation" (Gee, 2005, p. 22). The first sentence is populated with the student's "lifeworld" voice, whereas the second sentence required students to shed their identity and gain an abstract viewpoint that is not relevant in their daily life (Gee, 2005, p. 23). So if students are to undergo this transformation that represents a loss in linguistic identity, they need to learn to value the language of science and understand why it is used (Gee, 2005, p. 23). Additionally, students cannot begin to value and appreciate a language, until they understand its uses and how it constructs meaning. Since meaning in language is dependent on the context, students need to be immersed in the situated context of the language of science to develop any type of fluency (Gee, 2005, pp. 24-25). As part of constructing meaning is communicating their "perspectives on experience" to others, another key component for student immersion in the language of science is dialogic interaction with others who have mastered the language, while the student is simultaneously in the process of learning the language (Gee, 2005, p. 28).

In response to allowing students to use both "lifeworld" talk and scientific language concurrently in the classroom, Gee (2005) notes that this approach can be helpful for students first gaining exposure to the language and process of science, and praises it as a tool for students as a "sense-making" tool as Bakhtin envisioned (p. 32). To demonstrate the conflict between everyday and scientific language, Gee (2005) transcribes two students investigating the properties of rust on different objects. In order to explain their hypotheses to each other, the students use colloquial phrases, such as "get rusty" and "put on," in an effort to "make sense of a problematic situation" (Gee, 2005, p. 32). The problem is that in allowing the students to use such language in the classroom undermines the scientific concepts being investigated. In the example, the students incorrectly make no distinction between the object "having rust" (a state) and "having rusted" (a process) (Gee, 2005, p. 33). By allowing students to have colloquial conversations about scientific concepts, this encourages them to "use deictics, vague references, and ambiguous structures that are resolved by the shared knowledge the interlocutors have of what they are talking about" (Gee, 2005, p. 33). Gee (2005) feels that everyday language has a place in the science classroom, specifically as a tool for making "integrative connections across domains," but teachers should be cognizant that students are using scientific discourse and building "systematic relations" when discussing scientific language (p. 32).

Alternatively, Roth (2005) acknowledges not only the need for familiarity with linguistic resources to more effectively learn science, but the importance of student ownership over the knowledge as well. Just as students are able to shift social languages in the many roles they play in everyday life, students also have the ability to speak in scientific terms, satisfying class requirements without actually understanding the content (Roth, 2005, p. 180). Furthermore, research shows that students are more likely to adopt ways of speaking and practices introduced by students over ones introduced by the teacher (Roth, 2005, p. 181). As demonstrated in his case study, a guided discussion about the behavior of simple machines resulted in students unknowingly defining established laws through the description of their observations. Parallel to the study done by Zack and Graves (2001), these laws were then thereafter named for the students that first brought them to the discussion (i.e. Laura's Law). The notes of all contributions from the class that led to the discovery also referenced the students involved by name, as an attempt to encourage student ownership, and demonstrate what the class had accomplished (Roth, 2005, p. 188). While the results of the experiment showed positive effects, that students remembered the laws and used them fluently by their class-given names, some students still had difficulty relating the student discussions to the established scientific definitions and processes, and referred to the “student laws” as a process they were now aware of, but were not completely sure of how they worked (Roth, 2005, p. 197).

When Roth (2005) followed up this experiment with an investigation of how quickly students would appropriate the scientific language introduced by the teacher, he determined that the students absorbed the new vocabulary quicker than he had previously hypothesized (p. 208). From this study, Roth (2005) concluded that student achievement does not necessarily result from a student invention of language. Rather, as Bakhtin postulated, students will determine new linguistic needs and populate existing words with their own meanings and intentions (Roth, 2005, p. 208). As a solution, teachers and curriculum designers should not concern themselves with providing students the chance to invent language, but instead provide opportunities to collectively construct – between peers and the teacher – a common way of talking science (Roth, 2005, p. 209). If the starting points are from a place where both the teacher and students have a common understanding of the topic, by collaborating on making sense of these situations, students can assimilate the linguistic resources provided by the teacher while finding a new way to talk about the scientific world (Roth, 2005, p. 209). Through collectively constructing the meaning behind the scientific conversation, teachers can avoid using authoritative language by imposing definitions and decrease the negative interactions with the students’ own previously held misconceptions.

So far, there has been a lengthy discussion on science as a social language and the role that the language of science plays in student learning and building scientific literacy. In almost all of the studies presented, the common thread has been the necessity for social dialogic interaction for students to construct scientific meaning (Gee, 2005; Kelly, 2007; Leach & Scott, 2003; Lemke, 1990; Osborne, 2007; Roth, 2005; Tabak & Reiser, 1999). Science curriculum authorities would also acknowledge that there is a fundamental difference between how the term 'discussion' is frequently used in the science classroom; describing any type of verbal interaction between the teacher and students, and what a true science discussion is; an open conversation about a topic where students and teachers contribute equally to the dialogue (Chiappetta & Koballa, 2002, p. 111). Chiappetta & Koballa (2002) identify three possible structures for leading discourse in the science classroom: recitation, guided instruction, and reflective discussion; the last of which being the most effective and the closest to a true dialogic classroom (p. 113). While recitations and guided instructions are centered on pre-determined facts learned out of a textbook, a reflective discussion conversely challenges students to think creatively and critically to solve problems, while requiring that students justify their responses with empirical data (Chiappetta & Koballa, 2002, p. 113). Most importantly, one of the key parts of a successful reflective discussion is for the teacher to acknowledge the multiple voices in the classroom, and to use each response to construct the collective meaning of the class (Chiappetta & Koballa, 2002, p. 116). These recommendations support the argument for Bakhtin's dialogism as a pedagogical tool in the classroom, therein allowing for the heteroglossia of the classroom to collectively construct scientific meaning through dialogue and discourse using the social language of science.

A study done by Warren and Rosebery (1995) applies Bakhtin's theory of dialogism to demonstrate how learning in science results from social interactions in the classroom. In the study, a conventional science classroom engaged in a Triadic dialogue (teacher initiation – student response – teacher evaluation) is contrasted with that of a classroom engaged in true "meaning-making activities" (Warren & Rosebery, 1995, p. 8). In the case of the conventional science classroom, the teacher portrays science as a body of knowledge and rejects any student input that does not fit into the Triadic dialogue structure (Warren & Rosebery, 1995, p. 9). By not allowing the students to debate, to challenge the rationale for theories presented, nor to construct their own meaning through dialogue, the teacher acts in an authoritarian sense in Bakhtinian terms (Warren & Rosebery, 1995, p. 9). Furthermore, as a reaction to the oppressing attitudes of the teacher, the students evoke a carnivalesque reaction by further challenging the teacher with questions, and yielding to laughter and mocking of the teacher (Warren & Rosebery, 1995, p. 9). What makes this detrimental to the student learning though is that the teacher merges "his own authority with that of the scientist" (Warren & Rosebery, 1995, p. 11). As a consequence, if the students wanted to continue their dialogue that contests the findings in the theory, they now must challenge "the whole edifice of scientific authority, not just their teacher" (Warren & Rosebery, 1995, p. 11).

In a demonstration of how scientific arguments should be supported always with empirical evidence, the Warren and Rosebery (1995) juxtapose the aforementioned conventional science classroom with a true dialogic interaction observed in another science classroom. In this series of interactions, the students and teacher engage in a dialogue that is structured around a student's claim, his peers' challenge to his claim, and his efforts to support his argument with empirical evidence. "Through such *interanimation*, one perspective is evaluated from the point of view of another, creating a space within which new meanings can emerge" (Warren & Rosebery, 1995, p. 11). It is this act of engaging in true discourse, that is so crucial to the process of science, and by extension, student understanding of the process of science. Warren and Rosebery (1995) note that "scientists transform their observations into findings through argumentation and persuasion, not simply through measurement and discovery" (p. 18). Consequently, Warren and Rosebery (1995) stress the need for "communities of scientific practice" in the classroom where students act as scientists - by investigating their own questions, supporting claims with empirical evidence, and being critical of other student's findings to help refine each other's understanding (p. 12). Their findings argue that it is through these interactions, that the true science curriculum can emerge, one that is different than the pre-determined facts that students are expected to learn in most science classrooms (Warren & Rosebery, 1995, p. 12).

Another research study performed by Rosebery, Ogonowski, DiSchino, and Warren (2010) investigates Bakhtin's notion of heteroglossia as a fundamental condition of the learning process – and more specifically within this research – that of a science classroom learning about the transfer of heat and the particulate nature of matter. Rosebery et al. (2010) envision Bakhtin's concept broadly to encompass not just the differences amongst languages by their vocabularies, but also in the differing points of view of the students and how they conceptualize the world around them (p. 6). It is the opinion of Rosebery et al. (2010), that the growing diversity of schools should not be viewed as a 'problem' for educators (p. 2), but rather, an opportunity to provide students with the chance to participate in 'heterogeneous meaning-making practices' where students "generate new understandings, extend navigational possibilities, and adapt meaning-making practices to new forms and functions" (p. 4). Furthermore, by ensuring that all voices and perspectives have equal contributions to the dialogue, there will be an increase in contribution from students that are part non-dominant groups, intensifying the positive effects on the learning for all students in the classroom (Rosebery et al., 2010, p. 14).

In the context of this research study, Bakhtin's concepts of dialogism and heteroglossia are examined through a lens of an elementary school science classroom with a broad range of cultural and linguistic diversity amongst the students. In order to truly engage the students in scientific dialogue, the teachers in the study constructed a participation structure named "Sherlock," a name created by the students that describes the inquisitive nature of the activity (Rosebery et al., 2010, p. 14). Students are explicitly taught the difference between the common "school talk," a teacher initiation-student response-teacher evaluation pattern, and that of "Sherlock," where students have some control over the direction of the dialogue and the teacher plays the role of the facilitator giving each student a chance to participate (Rosebery et al., 2010, pp. 13-14). After identifying the major learning objectives for the unit, the teachers let the "evolving view of the children's understanding" of these concepts guide the construction of the lessons during "Sherlock" (Rosebery et al., 2010, p. 15). As a result, the teachers kept transcripts of the student discourse during each lesson, and used them to plan the subsequent lesson after reviewing where the students were in their understanding (Rosebery et al., 2010, p. 15).

During the course of the study, the teachers were cognizant of maintaining equality of all voices by placing an equal emphasis on teacher-led activities, to that of instruction that emerged from student inquiry and contributions (Rosebery et al., 2010, p. 49). Within the context of the classroom, the students used their own everyday ideas, cultural perspectives, and their own "ways of knowing" to describe scientific phenomena in ways that made sense to themselves individually (Rosebery et al., 2010, pp. 49-50). In fact, one of the unforeseen benefits of this study was the ways the students' varied perspectives forced a blending of physical world and simulated theories, as the students tried to make sense of this phenomena collectively. This behavior parallels a routine process for scientists grasping to understand as they analyze new models of systems (Rosebery et al., 2010, p. 50). These results demonstrate the robust number of learning opportunities that can result from facilitating heterogeneity in the classroom, and when the teacher uses the classroom's diversity to enhance students' learning (Rosebery et al., 2010, p. 52).

In yet another study supporting the benefits of a dialogically-structured curriculum, a linguistically diverse second grade classroom was observed for the inquiry and idea generation that naturally occurred during dialogic interactions. As a major platform for their research, Varelas, Pappas, and Rife (2005) used Bakhtin's theories of dialogism, and more specifically, how the students solved scientific problems through "a continual weaving and reweaving of responsive utterances" (p. 141). More specifically, Varelas et al. (2005) investigated the role that "intertextuality," or the "juxtaposing of texts," played as an essential process that students undergo to make connections between their lives, classroom activities, and texts (p. 141). For the context of this study, a "text" was defined as a "representation of meaning using a conventional symbolic system" and included textbooks, formulas, oral speech, or previous experiences (Varelas et al., 2005, p. 141). While not every utterance in a scientific discourse are built off of an intertextual link, the large amount of references that were warranted a further investigation on the role they played in the student dialogue (Varelas et al., 2005, p. 143). In recording and transcribing the dialogue in the second grade classroom, Varelas et al. (2005) were able to determine which utterances contained intertextual links, and showed that not only was meaning co-constructed amongst the students in dialogic interactions, but that the intertextual references provided even more opportunities to develop student understanding (p. 158).

Further applications of Bakhtin's dialogism are seen in a series of interrelated writings from different vantage points in an elementary school classroom. Doig (1997), Groves (1997), and Williams (1997) all investigated the role that dialogue plays in supporting students' learning and conceptual development, and more specifically, learning defined by a conceptual change. Groves (1997) states that a student experiences 'cognitive conflict' when a student's previously held conceptions are challenged – either through conflict with other's beliefs or the student's own inconsistent perceptions – which then forces students to re-evaluate their previously held views (p. 2). Bakhtin defined this as a necessary differentiation between interlocutors, where opposing voices in the dialogue have distinct positions (Marchenkova, 2005, p. 179). Or in other words, if there is not another perspective to challenge the student's belief system, than the dialogue is monologic in nature and no learning can occur. While all conflicts do not always ensure conceptual development, research shows that more powerful sources of cognitive conflict arise when students are forced to defend their views to others. As a result, teachers should construct learning opportunities where students are forced to provide empirical evidence to support their views in the face of others' conflicting beliefs (Groves, 1997, p. 2). In order to facilitate true dialogue in the classroom, teachers should "elicit views and opinions; assist in clarification and ask for restatement; explicate student's views; seek consistency; request definitions; search for assumptions; indicate fallacies; request reasons; ask children how they know; and help children examine alternatives" (Doig, 1997, p. 7).

Given that not all dialogical conflicts lead to cognitive conflict and conceptual development, the major question that this study set out to answer was to determine what environmental factors were necessary for the students to produce true scientific dialogue. Once determined, the results could be used to "inform teachers how they might better foster effective learning through discussion based on shared experiences" (Doig, 1997, p. 2). As with other studies, this one also emphasized the distinction between 'discussion,' a term used to summarize the general verbal interactions between teachers and students, and that of genuine scientific dialogue, which Doig (1997) claims is extremely challenging for teachers to organically facilitate in the classroom (p. 2). In a discussion, students and their teacher may exchange ideas through verbal interaction, however, these verbal interactions are structured so that the transfer of information is one-directional, usually teacher-to-student, and structured so that the teacher owns the knowledge (Doig, 1997, p. 4). Conversely, true scientific dialogue in the science classroom can be produced by a teacher and her or his students trying to answer a 'real' question collectively, while providing supporting arguments to their ideas (Doig, 1997, pp. 15-16). To test these theories, Doig (1997), Groves (1997), and Williams (1997) all attempted to stimulate cognitive conflict in a group of students working towards a common understanding of a testable concept, by controlling data so that it clashes with previously held misconceptions by students (Groves, 1997, p. 3).

For this study, the researchers observed a small group of elementary students engaged in a dialogue around the results of a lab experiment that challenges their preconceptions of how gravity behaves. A perceived error in the data collection leads to a dialogue amongst the students where they collectively make sense of the erroneous data together. For their activity, the students were instructed to measure the time an object takes to fall under the influence of gravity in order to test the nature of how gravity behaves. Since the concept of gravity is something that all of the students have previous experience with, every student came to this activity with strong convictions about how they perceive it to behave. However, when the collected data was contradictory to their predictions, all the students but one quickly dismissed the collected data as erroneous (Groves, 1997, p. 6). The one outlier student was able to question his own intuition, and postulated a possibly new explanation of how gravity behaves, which was met with great opposition by the others student who still had not accepted that their own understanding of the concept could be faulty (Groves, 1997, p. 5). Through argument and dialogue amongst the group, the students who believed the data was faulty repeatedly failed in finding ways to defend their misconceptions, which eventually led to a general consensus amongst the group that the data was in fact correct, and a ‘new understanding’ of how gravity behaves for all the students involved (Groves, 1997, p. 6).

From this study, Doig (1997) was able to detail some specific observations about the structure necessary to generate dialogic cognitive conflict that ends in conceptual change. Echoing Bakhtin’s theory of heteroglossia, a key ingredient in creating true dialogue was the fact that all students’ arguments and suggestions were given equal merit, and no one member of the group held a more authoritative role in the discussion over another, which provided the necessary difference in interlocutors (p. 16). Even when the teacher joined the dialogue, he remained an equal participant that supported student input and was conscious to not make his voice more important than anyone else’s (Doig, 1997, p. 16). In addition to the teacher’s role in managing “dialogic conversation” instead of a “discussion,” the teacher was also successful in facilitating the dialogue between the students by challenging them to support their assertions, and encouraging them to consider each member’s contributions (Doig, 1997, p. 16). The role as the teacher in the dialogic conversation is that of being under constant tension – searching for balance between advancing the dialogue of the group and checking for student understanding –

while truly understanding the beliefs and intentions of the learners (Williams, 1997, pp. 11-12). The teacher must truly understand what the student understands, and how the student is growing cognitively during the learning process (Williams, 1997, p. 12). Therefore, Williams (1997) argues that listening and summarization skills become invaluable pedagogical tools for science teachers as they try to facilitate true scientific dialogue in their classroom (p. 13). When viewed in this context, the importance of the teacher's voice as an integral part of the dialogue, as one voice of many in the heteroglossia of the classroom, becomes clearer when compared to outline of the role of the teacher in other studies (Warren & Rosebery, 1995); (Clarke, 1988).

As well as being mindful of the role that the teacher plays in facilitating dialogue in the classroom, science teachers must construct learning activities that support 'generative' interactions between students versus that of 'authoritative' interactions (McDonald & Abell, 2002). Authoritative interactions tend to be structured as monologue, where the speaker simply conveys meaning to the listener (McDonald & Abell, 2002, p. 10). Generative interactions, by comparison, tend to be dialogic in nature (McDonald & Abell, 2002, pp. 5-6), where the participants in the dialogue generate meaning (p. 10). By contrasting two different student presentations from on lab results, the learning opportunities that result from generative interactions become apparent. In one group, the students stuck to a straightforward presentation of lab results, kept peers out of contributing to the conversation, and stopped any generative conversation by not acknowledging their peers' contributions (McDonald & Abell, 2002, p. 3). The contrasting group organically started generative conversations with the class during their presentations, and as a result, maximized both their peers' and their own learning opportunities (McDonald & Abell, 2002, p. 3). Just as the teacher's voice should be equal to that of the students in the dialogue, students can benefit in the learning process through engaging in dialogue with their peers.

In an investigation of the benefits of having students engage in instructional dialogues amongst peers, Gorsky, Caspi, and Tuvi-Arad (2004) surveyed students in a distance-education chemistry course about their peer interactions and other instructional resources. For the purposes of this study, Gorsky et al. (2004) defined 'intrapersonal instructional dialogue' as "an internal process through which learners construct understanding," whereas 'interpersonal instructional dialogue' is a discursive process that requires an interaction (either teacher-learner, or learner-learner) (p. 4). For this chemistry course, students were provided with a variety of structural resources to assist with the learning process, some which supported intrapersonal dialogue such as self-instruction texts, and some which supported interpersonal dialogue such as web site discussion groups (Gorsky et al., 2004, p. 7). With aims to improve distance education in general, Gorsky et al. (2004) hoped to find which dialogic interactions and resources were more well-received by students by measuring student performance and interviewing both students and professors about the learning process (p. 8).

The results of the study showed that when the students were confronted with conceptual difficulty in the course, all students but one sought out some form of interpersonal dialogue to receive assistance, whether the dialogic interaction was teacher-learner, or leaner-learner (Gorsky et al., 2004, p. 13). Furthermore, when interviewed, a majority of students reported that peer collaboration, or learner-learner dialogues, was the most effective method for receiving help in solving problems and overcoming conceptual difficulty, with teacher interactions sometimes reported as a last resort (Gorsky et al., 2004, pp. 12-14). While Gorsky et al. (2004) highlight some potential influencers on the student reporting preference towards learner-learner interactions, such as unlimited access to peers versus professors; it does not change the importance for interpersonal instructional dialogue in order for students to overcome conceptual difficulty (pp. 16-17). By contrast, the study also found that all students, regardless of what they reported as their preferential method, engaged in intrapersonal dialogue as their primary method of actually learning new material. Gorsky et al. (2004) attribute this to the structure of many science courses at a university level:

> Science courses, especially an intermediate-level chemistry course, are not generally discussion-oriented. Science is still too often seen by science educators as an external, objective body of knowledge to be transferred to the learner, either through self-study texts or lectures. The role of dialogue is as best explicative, occurring when a learner does not understand some concept or is unable to solve some problem. Although constructivist approaches to science education…show the need for and advocate discursive approaches to the acquisition of scientific concepts, this is still too infrequently implemented in university-level courses. (p. 17)

While these findings and suggestions by the authors are aimed at university-level distance education classes, the importance of dialogic-driven instruction in the science classroom is as important for science classrooms of all levels.

In a follow-up study, Gorsky, Caspi, and Smidt (2007), investigated similar outcomes to their 2004 study for students taking a difficult distance education physics course. Done on a larger scale with a more challenging course, the results of the study echoed many of their previous findings, in that most students used intrapersonal dialogue as primary means of overcoming conceptual difficulty, but many found interpersonal dialogue the more effective means of doing so, and without interpersonal dialogue, many would never have overcome these difficulties (Gorsky et al., 2007, p. 16). In the study, the data shows that many students, after trying to overcome conceptual difficulty through intrapersonal means, finally were able to with some means of interpersonal dialogue, even though the students credited their own contributions more to their learning process than crediting others (Gorsky et al., 2007, p. 16). While this may be a result in human bias to credit oneself with their own triumphs (Gorsky et al., 2007, p. 16), it may also be a reflection on the decreased emphasis on interpersonal dialogue in the learning process for the sciences. That is, many teachers are not familiar with how to appropriately use dialogic interactions as pedagogical tools, and students are not aware of its effectiveness on their learning process.

Applications of Bakhtin's theories for the science classroom can boost teacher effectiveness and improve general student performance, but they can also have a profound effect on a large group of students who need differentiated instruction. Research supports the claim that the majority of students who do not fit into the dominant cultural/racial/gender groups tend to perform lower that their peers in the science classroom (Roth & Barton, 2004, p. 129). This disparity stems from traditional teaching methods in science classrooms tending to favor Caucasian middle-class males, while the rest of the students not in these demographics unfortunately are excluded from the learning process (Roth & Barton, 2004, p. 129). Other studies showed that the performance gap between these groups of students lessened when the class was taught with curriculum that was student-focused and discourse-based (Roth & Barton, 2004, p. 129). Furthermore, students who participated in the study and were labeled by the school as learning disabled or socially disadvantaged, tended to outperform many of their peers who traditionally performed better (Roth & Barton, 2004, pp. 129-130). In a separate study, as part of their college capstone project, students were required to write a dialogue representing two different perspectives on a biochemical topic with a social and/or ethical component (Roberts-Kirchoff & Caspers, 2001). In completing this project, students were given the chance to engage in a much higher thinking process, since the students had to summarize this information internally before presenting it to their audience (Roberts-Kirchoff & Caspers, 2001, p. 227). In addition, the teachers were able to include voices from the scientific community by inviting guest scientists to watch the presentations and interact with the students (Roberts-Kirchoff & Caspers, 2001, p. 227). While this activity was intended for a more advanced student, the activity could be replicated as an alternative assessment for any grade level and subject area by allowing students to answer their own scientific question, followed by a presentation of their answers to an outside audience. Finally, for students who have limited proficiency in science or in the language the course is being taught in, teachers can construct classroom activities that provide students the chance to contribute limited knowledge about the content area as a way to invite them to join the conversation (Kelly, 2005, p. 98). For example, when learning about the behavior of light, all students can contribute to the beginning conversations on how light reflects, even if they are not able to fully define the scientific abstraction at first (Kelly, 2005, p. 97).

To further explain the benefits of using dialogic-based activities, one can draw on the theories of Lev Vygotsky (1896 – 1934), a Russian psychologist who shared similar theories with Bakhtin and more specifically Vygotsky's thoughts on the "Zone of Proximal Development." Vygotsky's theory of the Zone of Proximal Development can be summarized as the "distance between individual, unaided performance, and performance under guidance (Roth & Barton, 2004, p. 73). Teachers should view learning activities that have students talking about science with each other and with members of the science community as a way of constructing a "zone of potential learning and development that allows collective bodies to produce and further develop ability" (Roth & Barton, 2004, p. 152). Dialogic activities with peers, teachers, and members of the science community are beneficial for all students, regardless of their ability level, because in these conversations, the learning disability does not stop them from participating. Rather, the conversation can move with fluidity, building only on what the student can accomplish (Roth & Barton, 2004, p. 152). By allowing for other means of instruction and assessment, students who struggle with traditional approaches, such as paper-and-pencil tests, are able to express what they have learned through whatever learning style works better for them (Roth & Barton, 2004, p. 130).

As has been previously mentioned, Bakhtin felt that the written word was dialogic in nature as well, (Zack & Graves, 2001, p. 231), and as such, the role of dialogue in the science classroom is not only restricted to the spoken word. Kubli (2005) argues that in a literature classroom, students are trained to distinguish between the voices of the author of a text, the *implied* author of the text, and the voice of the teacher interpreting the author's work (p. 511). Comparatively, students in the traditional science classroom are not exposed to the voices of the scientists that postulated the theories they are studying, but rather the students are exposed to the authoritative voice of the prescribed textbook (Kubli, 2005, p. 511). Furthermore, teachers are never taught, nor encouraged, to demonstrate how actual scientists communicate new findings through reports and papers; resulting in a classroom where students develop a misleading perception of the nature of science (Kubli, 2005, p. 511). Through student interviews, Brown (2006) also found that even though students had a sophisticated view of what scientists do and how they behave, students did not include themselves as part of the scientific community, nor feel the confidence that they could make significant written contributions to the field (p. 115). In order to stimulate interests among students for reading and writing science, it is crucial that teachers give the scientists a voice by showing processes that led to scientific discoveries, and allow digressions that show students using scientific thinking in everyday life (Kubli, 2005, pp. 511-512).

Since textbooks are a sometimes necessary evil of the modern classroom, Kubli (2005) also suggests that teachers must be aware of the significance placed on the textbook as absolute fact, and should set more emphasis on activities in the classroom that mediate between the students' way of thinking, and that of the textbook (p. 513). Since the laws of science can be interpreted as "soundless," the teacher must manipulate the presentation of these laws, with specific focus on voice inflection and avoiding monotonous tones (Kubli, 2005, pp. 518-519). By doing so, this can produce a more dialogistic approach between textbooks and students (Kubli, 2005, pp. 518-519). In addition to the voices of the students, teacher, scientists, and textbook, there is one more important voice that is usually lacking in the classroom; "echoes" of the voices of important scientists whose only contribution to the current conversation are the theories they left behind (Kubli, 2005, p. 520). Differing from the voice of the general scientists and the scientific process discussed earlier, by bringing in historical writings and stories around the scientists who discovered the laws in the textbook conjures an emotional and social connection for students (Kubli, 2005, p. 521). By bringing in the historical perspective, students can learn about a scientist, read how she or he came to perform their famous research, and then recreate the study in the classroom with classroom activities; all which sheds a tremendous amount of insight into a scientific way of thinking (Kubli, 2005, p. 516). When developing science curriculum, teachers should be cognizant of using their own voice and textbook as a necessary component in the classroom, but not as the authoritative voice (Fecho & Botzakis, 2007, pp. 548-549).

One of the most common written activities that are frequently implemented in all science classrooms is that of a lab report. However, when analyzing students' written lab reports on their lab findings, Kelly & Chen (1998) found that a majority of students were not gaining the full benefits of participating in such an activity, as they faced challenges with communicating in the 'language of science,' and failed to construct arguments using empirical evidence to support their claims (p. 36). In a different study, when asked to articulate their challenges with science, many students pointed to their inability to use the vocabulary and dialogic structure effectively to communicate through writing with each other and their teacher (Brown, 2006, p. 117). As one student states, there is no context for scientific words and discourse in everyday language and slang (Brown, 2006, p. 119). Even students that felt command over their ability to communicate through academic writing viewed scientific writing as a different process than in language arts and social studies classes (Brown, 2006, p. 118). These students were never explicitly instructed on how to communicate like a scientist, and so the students must be submerged in the language and cultural practices of the scientific community in order to construct their own perspective on who a scientist is and what they do (Kelly & Chen, 1998, p. 36). As part of their submersion in the scientific community, Kelly & Chen (1998) suggest that students should be engaged in written and oral dialogue with their peers and teacher, but also with the scientific texts and the other scientists in the field as well (p. 37).

In addition to challenges regarding being able to read and write science, many students who are not accustomed to the language of science and its use of foreign terms and thinking processes, develop a major disconnection between what is learned in the classroom and what 'real" scientists do. Since many students perceive science as a challenging subject, and view scientists as people with great skill and knowledge, many students, especially those from non-dominating cultural or gender groups, can feel an identity crisis when they identify themselves as intelligent but feel science is beyond their abilities (Brown, 2006, p. 98). For all of these reasons, science teachers need to be sensitive to how "linguistic differences and gender and ethnic identity conflict" can impact student achievement in science (Brown, 2006, p. 97). This is especially true when teaching students how to appropriately engage in scientific discourse, which can be the largest barrier in their attempts to "assimilate into the culture of science" (Brown, 2006, p. 121). By emphasizing scientific processes, such as argumentative discourse, instead of memorization of scientific fact, teachers can help students self-identify as part of their classroom community, as well as the scientific community (Kelly & Chen, 1998, p. 37).

One way to engross students in scientific writing while teaching students about the nature of science is through the use of Reflective Dialogue Journals, which are written journals that include student reflection and teacher response. A study completed by Ryan (2000) used these journals, their introduction was meant to reconstruct students' perceptions of how science functions as a field of study, to identify the limitations of the scientific process introduced in school, and to "highlight the dynamic, fallible, and context-bound nature of the discipline and value a diverse range of skills including creativity, and logic, intuition, and rationality" amongst the students (p. 4). In comparing the Reflective Dialogue Journals of two different students, the emerging trend from the journals was that the students that reflected on their understanding through dialogic writing demonstrated cognitive growth and personal ownership and performed better on assessments (Ryan, 2000, p. 6). Based on these results, it would seem that the students who performed better as a result of the journals were the students who constructed their own meaning of the nature of science through written dialogic interaction. In addition, by giving the student writing a voice and an audience, the student was able to populate the written words with their own writings.

Applications of Bakhtinian Carnival for Science Education

While a majority of this literature review has been dedicated to Bakhtin's theories of dialogism, there have also been references to Bakhtin's theories involving the festival of carnival, and more specifically, the evoking of the carnivalesque spirit by students in face of teacher oppression. However, Bakhtin's interest in laughter, play, and grotesque realism can also be used as pedagogical tools in the science classroom. Arguably more so than any other subject area, science education itself is innately grotesque, as it constantly challenges the hierarchy between humans and every other species on the planet, and forces students to view the natural world through different lenses (Weinstein & Broda, 2009a, p. 773). Even though the very content of science is playful and grotesque by nature, many teachers "reduce science to facts, memorizeables, and decontextualized knowledge," so that they can avoid the conflict that may arise (Weinstein & Broda, 2009a, p. 773). Instead of depriving students of the natural fun and grotesque experiences in the biology classroom, it should be used as "a tool used by teachers and students to alternatively command attention and disrupt authority" in the science classroom (Weinstein & Broda, 2009a, p. 762).

To demonstrate this relevancy of Bakhtin and the grotesque, note a very brief classroom interaction between the teacher and students involving a dissection, a very common assignment, with a moment of embracing play and Carnival. Before having students start a routine dissection on a pig's heart, the high school biology teacher instructs the students to hold the pig's heart against their apron in the place where their own hearts were located, eliciting a horrified and disgusted response from most of the students. With this request, the teacher was able to challenge traditional hierarchical structures; by having the teacher embrace the grotesque while the students embodied “propriety and the classical body,” and challenge cultural taboos regarding blood, dirt, and death (Weinstein & Broda, 2009a, p. 771). In addition, students were able to challenge hierarchies set up between humans and animals by recognizing the similarities between the pig and themselves (Weinstein & Broda, 2009a, p. 771). However, Weinstein and Broda (2009a) reason that the teacher’s actions were not simply carnivalesque, but instead have pedagogical ramifications as well (p. 772). By asking the students to place the pig’s heart where their own is located, the teacher was able to quickly assess which students knew this information, and was able to provide immediate remediation to the students who were not able to do complete this task (Weinstein & Broda, 2009a, p. 772). Furthermore, the teacher utilized the student reaction to the grotesque in order to capture student attention before instruction began, and ensured that students would be engaged for the duration of the lesson (Weinstein & Broda, 2009a, p. 772). Through this example, the teacher was also able to demonstrate a controlled application of carnivalesque behavior, to avoid distracting student behavior indulging in the grotesque outside of the structure of teacher-student interactions.

Other times, bringing aspects of carnival can help science teachers teach difficult concepts that would be otherwise too abstract for science students. Energy is a topic that even scientists struggle with providing a concrete definition, let alone describing how it behaves. Nonetheless, energy in its various forms and laws involving its behavior are concepts taught at almost every grade level in every discipline (Van Hook & Huziak-Clark, 2008, p. 1). To complicate the issue, many students come to the science classroom with everyday experience and "lifeworld" ways of describing energy (Van Hook & Huziak-Clark, 2008, p. 2). By bringing everyday toys into the classroom, such as a slinky or toy car, teachers can boost student conceptual understanding of energy, while providing a temporary escape into carnivalesque play (Van Hook & Huziak-Clark, 2008, p. 3). As another example, a simple trip to a local playground can substitute as a physics laboratory full of invaluable lessons about mechanics, while providing students the opportunity to engage in laughter and play, no matter what age group (Van Hook, Lark, Hodges, Celebrezze, & Channels, 2007, p. 85). The possibilities for integrating aspects of carnival into the science classroom are detailed and endless, but the main take-away for teachers is that rather than avoiding or displays of play and the grotesque from students during lab investigations, teachers should instead use it as a critical pedagogical tool when teaching (Weinstein & Broda, 2009a, p. 778).

The Teacher's Role in the Dialogic Science Classroom

This review thus far has taken a critical look at theories of Mikhail Bakhtin and dialogic pedagogy in an attempt to improve science curriculum and instruction and to further engage students in the content and improve scientific literacy. While many studies have discussed the positive attributes and behaviors that teachers must display in their effective implementation, there still warrants a thorough investigation into how teacher ability and performance can be detrimental to student engagement in science, even with dialogic pedagogy in place. When teachers dominate the science classroom discourse with monologic, authoritative points of view, not only could they be limiting the effectiveness of their instruction, but the resulting effects on student learning can detrimental as well. A study done by Clarke (1988) investigated the simple dialogic interactions between the teacher and students in a science classroom, in an attempt to quantify the structure and content of the conversations being held. In a comparison to control groups, student achievement on science performance tests was overwhelmingly influenced by the dialogic structure between the teacher and the student (Clarke, 1988, p. 7). The problem, Clarke (1988) proposes, is that in ineffective classrooms, teachers are acting as a "surrogate textbook" by using their own organization and structure of the knowledge, which may be wrong or incomplete (p. 7). While the author in this study does not directly reference Bakhtin or his concept of heteroglossia, the interpretation of the results of this study can be viewed through a Bakhtinian lens. By making the conversation a monologue, or in other words, when a teacher only presents their perspective of the knowledge, the teacher does not allow students to make their own meaning of the content, and will be ineffective in their attempt to 'transfer knowledge' to students. The end result, as also seen in Warren and Rosebery (1995), is the merging of the teacher's authority with the authority of the textbook, and students evoking a carnivalesque reaction to the forced content.

According to Bakhtin, "communication is only meaningful if we know the circumstances – even if the communicative act itself consists of only one word" (Kubli, 2005, p. 513). This means that effective transmission between interlocutors in teaching relies on three conditions – shared experiences, shared knowledge, and a common evaluation between the two in dialogue (Kubli, 2005, p. 513). In the science classroom, a teacher creates a shared experience by performing a class demonstration, or having students perform an experiment, so that everyone in the classroom has experienced the phenomena being discussed (Kubli, 2005, p. 514). Subsequently, to build a shared knowledge of the concepts at hand, science teachers must use sound logical arguments to assist students from their original way of thinking, to a shared knowledge with the instructor (Kubli, 2005, p. 514). Finally, a science teacher must consciously strive to build a common evaluation of the learning activity with the students. In other words, the student may receive the information about the results of an experiment, but if the student does not share the same enthusiasm that the teacher does about the outcome, the student will lose interest and fail to fully receive the attempted transmission (Kubli, 2005, p. 514). The shared emotional investment in the subject matter, or at least an attempt to communicate excitement on the teacher's part, is something that can increase instructional effectiveness, but unfortunately does not receive enough attention in the classroom (Kubli, 2005, p. 515).

Research done by Kelly and Chen (1998) also shows that when teachers were less confident with the content material being presented, they were more likely to adopt an authoritative position, presenting content as absolute fact and avoiding questions that supported critical thinking and discourse (p. 11). This phenomenon was even observed within two courses taught by the same teacher; who engaged his biology students with complex questions and dialogue, but then presented his chemistry students with prescribed facts due to his mismatched levels of expertise (Kelly & Chen, 1998, p. 12). Presenting information in "compressed, dense forms" makes the content materials less accessible for students, and presents science as a field of study that students feel they cannot participate in (Kelly & Chen, 1998, p. 12). In another example, a teacher asks students to identify physical characteristics of different animals, when a student unexpectedly tries to contribute to the conversation by discussing the animal that is his pet (Liberg, Geijerstam, & Folkeryd, 2007, p. 21). While the teacher dismisses this students' answer because it's not 'relevant' to the conversation, the authors note that this student was in fact contributing to the dialogue within his own cultural experience (Liberg et al., 2007, p. 32). What this student had produced is what Liberg et al. (2007) refer to as 'the produced text,' in contrast to the 'real text,' or the relevant content matter as seen by the teacher (p. 43). Since the teacher controls the norms of what is considered the ‘real text’ and the ‘produced text,’ teachers should be aware to not discourage students from contributing to the dialogue by constructing very structured conversations (Liberg et al., 2007, p. 43). As an extension, a difference in conclusions between lab groups should not equate to a better or worse grade for a group, but rather it should become a ‘teachable moment’ for the students to argue and explain their findings (Fecho & Botzakis, 2007, pp. 548-549).

Zeidler (2007) asserts that the ability to communicate about science intelligently is a mandate for up-and-coming generations who will be faced with growing moral and environmental concerns regarding science and technology (p. 81). However, many teachers do not recognize the sociolinguistic benefits that science inquiry has for all classes (Kelly, 2005, p. 98). An impromptu science lesson in any classroom can foster an atmosphere of inquiry, discussion, discourse, and critical thinking when pursued (Kelly, 2005, p. 93). In one example, before starting a math lesson in her elementary school, a teacher was interrupted by two students who asked about curious behavior of the animals in the marine tank. Instead of dismissing the question for the sake of the lesson, the teacher admitted she did not know and turned the question around to the class to see if any of the students had any ideas to explain the behavior, and if not, what resources they could use to answer this questions (Kelly, 2005, p .91). Engaging in scientific dialogue can provide students with the opportunity to think critically and creatively about the world around, and foster problem solving and communicative skills that are useable in all content areas.

In light of these concerns about teacher ability and instructional pedagogy, Lemke (1990) provides a detailed account of ways that teachers can restructure their teaching methods to accomplish genuine dialogue and improve scientific literacy. First, students must be given more practice in dialogic conversations and debates using scientific language (Lemke, 1990, p. 168). Second, teachers must provide students with a framework for combining abstract scientific terms into complex sentences that demonstrate knowledge of semantic patterns (Lemke, 1990, pp. 169-170). Third, many teachers are quick to dismiss the commonsense answers and anecdotes students bring to the classroom, as was presented in the example of the discussion of heat and light energy. However, allowing students to provide input into the conversation gives students' ownership in the discussion, and provides teachers with the opportunity to assess student misconception (Lemke, 1990, p. 171). Once the misconception has been stated and discussed, then the class and teacher together can collaborate on how accurate the student's theory is or is not. Taking this step even further, teachers need to highlight the differences between formal scientific style and informal language. Activities can be formed where students translate colloquial and everyday observations about the world to scientific explanations, to allow students to bridge the gap between these two seemingly different languages (Lemke, 1990, p. 172). In addition to understanding how to talk about science, teachers can help students understand the actual nature of science as a social human activity, the differences between theory and observations, and the process of science as another way of talking about the world (Lemke, 1990, pp. 174-176). Finally, teachers should find ways to "resolve conflicts of interest" between the science curriculum and the students' language and cultural values (Lemke, 1990, p. 178). By following these guidelines, science teachers can successfully implement Bakhtin's theories in the science classroom, and construct learning activities that attempt to improve student scientific literacy.

Implications for Science Teaching & Further Research

Over the course of this review, in efforts to find suggestions to better science instruction, I have provided an extensive review of secondary sources on the theories of Mikhail Bakhtin, and the available research that directly and indirectly applies his works to the science classroom. Through comparative analysis of these individual studies, it is possible to identify common findings that provide strong recommendations for how science curriculum should be structured. Numerous studies discussed the language of science as a social language envisioned by Bakhtin, and argued that it should be treated as such. Learning activities should be constructed for students that explicitly teach them the social language of science, and they should be provided the chance to engage in meaningful science talk with peers and members of the scientific community. As the body of knowledge that makes up the discipline of science is itself socially constructed, teachers should be careful to not present science textbooks as absolute fact, but rather use it as a scaffold that students can use to construct meaning. Given that Bakhtin believed the written word to be dialogical by nature, facts in textbooks should be given the voices of the scientists who discovered them. Students should be given assignments that either argue scientific findings, or further contribute to the body of knowledge in a field of science through their own written arguments. Lab activities should not just be hands-on, but designed so that cognitive conflict occurs that forces students to construct meaning dialogically. Finally, lab activities and demonstrations should be injected with elements of play and the grotesque that echo Bakhtin's perspectives on the celebration of carnival to engage students in the learning process.

Other studies demonstrate that even delivering student-focused activities that consist of students discussing scientific concepts is not enough alone to truly engage students in scientific dialogue. Teachers also need to be excruciatingly aware of their facilitating roles as the teacher; by providing enough input to drive discourse and ensure all students are able to contribute. Simultaneously, teachers need to be aware of mixing their voice with that of the science content, to avoid presenting debatable theories as authoritative fact. Instead of stifling student inquiry and contributions to the class discussion, teachers should encourage questions and challenges interjected by students, even if it comes at the expense of planned lessons. Alternatively to avoiding moments of play and laughter, teachers should embrace these moments of playful mocking of authority as potentially truly genuine learning moments. Most importantly, teachers need to re-insert themselves as learners in this collaborative process, where teachers have as much to learn as students from the classroom discourse, as that is the only true way knowledge can be constructed in the Bakhtinian sense. With all the parameters placed on the teacher in generating knowledge through scientific dialogue, both in the design of the curriculum and facilitation of the discourse, it is abundantly clear the importance of the role of the teacher. Therefore, it would make sense to support studies that demonstrate teacher ability to be the predominant indicator of student success in engaging in scientific dialogue.

However, the question remains, that if integrating theories such as Bakhtin's into the classroom requires expert teacher knowledge and skill, how can teachers implement these suggestions without the proper background and experience? As an alternate case study, the notion that science classrooms should implement more inquiry-based critical-thinking activities has been suggested by science curriculum experts for over a hundred years (Barrow, 2006, p. 266), and even today there is overwhelming supporting evidence for the effectiveness and necessity for it in the classrooms (Clewell, Consentino de Cohen, Campbell, & Perlman, 2005, p. 9). But as recent as 2002, studies found that more than 80% of schools in America were teaching science in a manner where students observed the teacher rather than practice science themselves (Jorgenson & Vanosdall, 2002). Pre-service teachers surveyed about their attitudes towards teaching inquiry-based science found that many teachers had many misconceptions and were scared to teach inquiry-based learning because they had never experienced an inquiry-based class themselves (Reiff, 2002, pp. 14-15). If the lack of teacher experience with inquiry-based learning is hindering its widespread acceptance, what then can facilitate the transition among teachers and break the "continued cycle of textbook oriented science" (Reiff, 2002, p. 19)? What would be the best way to develop teachers professionally to teach inquiry-based learning effectively? Can studies determine the effectiveness of new teachers who were themselves taught in an inquiry-based environment themselves within the past ten years?

Correspondingly, the same questions and concerns can be raised as professional theories, such as Bakhtin's, from the fields of sociology and linguistics are applied to science education. Can teachers ever truly subscribe to the concept of genuine scientific dialogue without experiencing it for themselves? Multiple studies assert that teachers not having a model of genuine dialogue could be a major obstacle to effective instruction (Leonard, 1999, p. 17; Osborne, 2007, p. 181; Zack & Graves, 2001, p. 234). As more sociolinguists contribute their expertise to this conversation, there may be an increase in prescribed science curriculum and textbooks that provide students the opportunities to read, write, and talk about science. However, as previously seen in this review, "talking about science" is quite different than the act of "science talk" (Lemke, 1990), and without appropriate training and development, teachers may not know how to effectively instruct using this pedagogy. Consequently, as the research on Bakhtin's theories clearly demonstrates the benefits of applying them to the science classroom, it now creates the need to research how they could be effectively implemented in the classroom.

Teachers should be surveyed for their attitudes and misconceptions regarding teaching through dialogic pedagogy, and be exposed learning new science through dialogic interactions to immerse themselves as a learner in the learning process. Mikhail Bakhtin's theories of language in a social context hold a tremendous potential to fix many of the problems with the current system of science education; however, it will take bringing science teachers into the dialogue before they can be effectively implemented.

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